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Composition and trophic structure of a fish community of a clear water Atlantic rainforest stream in southeastern Brazil

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Synopsis

As part of a larger project that aimed to determine the factors that regulate fish productivity in a clear water river of the Atlantic rainforest, São Paulo State, Brazil, composition and the trophic structure of the fish community of the middle course of the river were studied from January 1995 to May 1996. Of the 17 species collected, *Mimagoniates microlepis, Schizolecis guentheri, Phalloceros caudimaculatus* and *Kronichthys heylandi* accounted for 83.2% of the total fish abundance. Most of the species were insectivorous (35.7%), followed by detritivores (21.4%), benthivores (14.2%), omnivores (14.2%), herbivores (7.1%), and piscivores (7.1%). Results of food overlap analysis as calculated by the Index of Morisita showed that 17.5% of the species pairs overlapped. Habitat segregation, however was observed among most of the species, suggesting some degree of food partitioning. Despite the characteristics of this escarpment river, which produces spates year round, no seasonal variation in diet was observed, suggesting that although food abundance may fluctuate throughout the year, most items are in constant supply. The importance of allochthonous food was considered and it appears that, though only a few species feed on this source (including detritivores), they make up 87.2% of the total fish abundance. The low abundance of most of the fishes, the high number of endemic species and the strong dependence of the species on a few food resources suggest that these systems are sensitive to anthropogenic impacts and require future studies.

Introduction

Despite the sparse information that exists on the systematics, distribution and ecological aspects of fishes from the Atlantic rainforest of Brazil, it is well known that several species are threatened and that the destruction of the forest is considered one of the main causes of their elimination. The rainforest is known for its high percentage of endemic fish species, caused by the great number of independent hydrographic basins and the isolating effect of mountain ranges that separate fish populations in innumerable valleys (Buckup[1]). Angermeier & Karr (1983) suggest that large scale alterations in forest structure may have serious impacts on stream biodiversity, affecting effects of shading, discharge variability, siltation and available food types.

Although some studies on fish communities of clear water streams of the Atlantic rainforest describe community composition and main food habits of species (Sabino & Castro 1990, Uieda 1995, Buck 2000), several aspects of the ecology of these communities still remain unknown. As the escarpment clear water river here studied is subject to unusual conditions as spates throughout the year, which may provide changes

[1] Buckup, P.A. 1998. Biodiversidade dos peixes da Mata Atlântica. pp. 1–9. *In:* Base de Dados Tropical (ed.) Biodiversity patterns of South and Southeast Atlantic Rainforest. http://www.bdt.org.br/bdt/workmatasud/peixes.

in habitat structure and resource levels, the study of the pattern of resource use in such a system may help to understand how species interact and cope with the environmental fluctuations.

This study aimed at characterizing the fish community of the middle course of a clear water river (Pedra Branca River) under natural conditions, focusing on some aspects of the community strucuture and determining the main resource utilization patterns.

Study area

Pedra Branca River (23°44′S 45°48′ and 45°51′W) is a 6.0 km long, third order river originating at 900 m in the State Park of Serra do Mar and draining into the Vermelho River at sea level. Its basin is situated over igneous rocks, predominantly of granitic origin, rich in Si, Al and Fe oxides and poor in Ca, Mg, Na and K (Mason 1971).

Three major geomorphological units of the basin can be distinguished (Figure 1): (a) a high and medium escarpment region with a stream bed covered in rocks; (b) fluvial plain or marine terrace, where sandy-argillaceous sediments are deposited; (c) marine plain, close to sea-level, with low drainage density, and with sediments of marine and mixed origin (Ponçano et al. 1981).

At the higher section, where the river is of first order, the slope is more than 48%, attaining 24% on the second order stretch. The sampling sites were situated along the middle course of the river (third order), where slope is less than 3%. All the study area is situated within the geomorphological unit of the fluvial plain.

Aerial photographs of 1994 (scale 1: 250 000) showed that the watershed is covered by typical Atlantic rainforest mountain vegetation and the lower portion by coastal plain forest. Human habitation is limited to a small village of Guarani Indians, whose subsistence is based on the extraction of palm hearts (*Euterpe edulis*) and palm leaves. Outside the hydrographic basin there are some rural properties expanding in the direction of the basin, and degraded areas now in regeneration can also be observed, as well as the town of Boracéia. Since 1996 the Pedra Branca River has been used as the water supply for the urban area of Boracéia.

The climate in this region is hot and humid with mean annual temperatures of over 20°C and an annual rainfall between 2000 and 2500 mm (Santos 1965). Due to its geographic position, the weather in this region is constantly subject to the influences of maritime masses from the Atlantic Ocean (Cetesb)[2], resulting in high air humidity throughout the year, averaging around 80% (Figure 2).

Despite the absence of marked seasons, rains are more intense in October through March especially from January to March. Less rainfall occurs during the cold and dry season (April–September), particularly in the months of July and August (Santos 1965, Goldenstein 1972).

Material and methods

Sampling

The study was conducted from January 1995 to May 1996. Three sampling sites to determine fish community composition and abundance were chosen in the middle course of Pedra Branca River. Each site had an average length of 60 m and width of 10 m, and similar features of forest canopy, substrate and habitat diversity. A fourth site, located between Site 3 and 2, was chosen for the diet study of the fish community.

For the evaluation of fish composition and abundance, fishes were sampled every two months, using electrofishing (Honda generator, 1000 W, AC), which involved wading upstream and using three passes in each study. Fish were identified in the field, counted and measured, and released after the end of the sampling. Unidentifiable fish were preserved in 10% formalin for subsequent identification.

After electrofishing, bathymetrical maps were drawn for each particular site. Environmental variables, such as percent bottom substrate type and percent canopy tree shading were measured at each sampling site. Conductivity was measured with a portable conductimeter Digimed CD-2p, and pH with a pH meter Radelkis Mini-Digi-OP-113.

The climate of the region during the studied period is shown in Figure 2, indicating a high rainfall during the whole year, but especially in February and March, when total monthly values reached near 600 mm.

Diet analysis

For the diet study, fishes were collected monthly with the same electrofishing equipment, and specimens

[2] Cetesb (São Paulo). 1985. Baixada Santista: Carta do Meio Ambiente e sua Dinâmica. São Paulo. 33 pp.

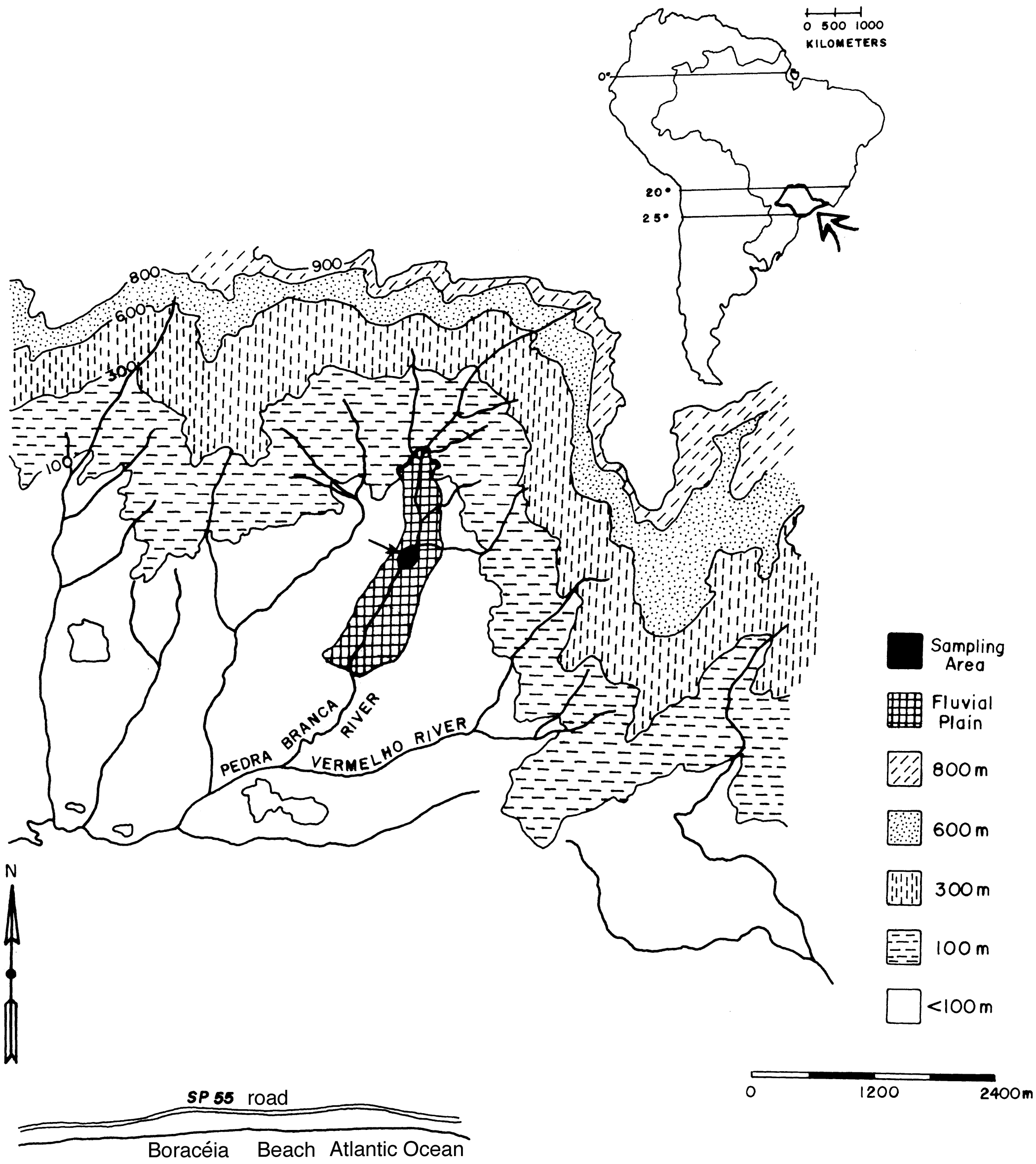

Figure 1. Location of Pedra Branca River in relation to planialtimetric isobaths and detail showing location of the studied area in São Paulo State, Brazil.

fixed in 4% formalin solution. Gut contents were analysed according to the method of frequency of occurrence (i.e., the number of stomachs in which a particular item occurs is expressed as a percentage of the total stomachs examined) (Hyslop 1980), and the points method (Hynes 1950), where items are examined under a counting chamber under a stereomicroscope (25×), and the area occupied by each item evaluated. The total area of food items was considered the total volume (100%). Calculations of the volumetrical proportion of each food item were made according to the formula:

$$P_{ij} = \frac{\sum_{x=1}^{N} P_{ix}}{N_j},$$

where P_{ix} is the proportion by volume of item i in the gut of the individual x and N_j is the number of individuals

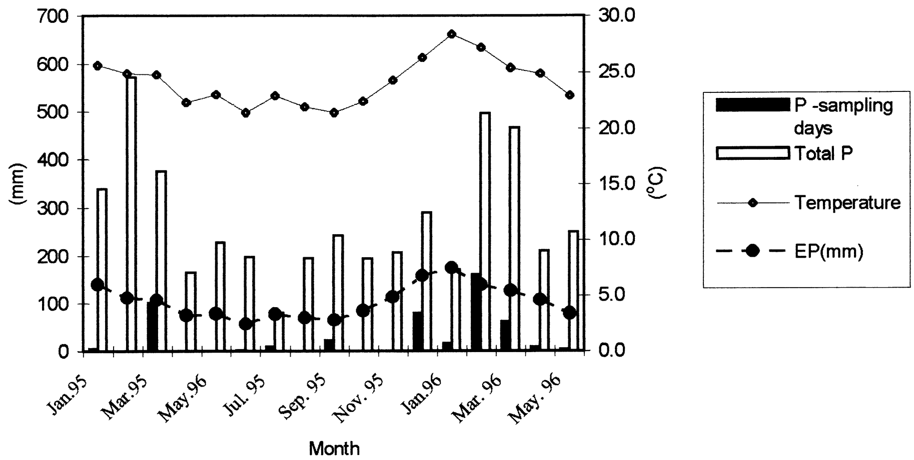

Figure 2. Climatological data for the period of January 1995 to May 1996, obtained from the Meteorological Station of Riviera São Lourenço, Bertioga, SP (P = total rainfall for the sampling days, total P = total monthly rainfall, EP = evapotranspiration).

of the species j. Food items were determined to the most detailed level possible.

To estimate the predominant food item, frequency of occurence and points method results were combined according to the index proposed by Kawakami & Vazzoler (1980):

$$IA_i = \frac{F_i x V_i}{\sum_{i=1}^{n}(F_i x V_i)},$$

where IA is the food index; i = 1,2,. . .,n food item; F_i = frequency of occurrence (%) of a given food item; V_i = volume (%) of a given food item.

The food overlap coefficient of Morisita modified by Horn (after Zaret & Rand 1971) was used and calculated with respect to the results obtained by the points (volumetric) method. The coefficient (Cλ) varies from 0 when samples are completely different, to 1 when the samples are identical with respect to proportional food category composition:

$$C\lambda = \frac{2\sum_{i=1}^{s} X_i Y_i}{\sum_{i=1}^{s} X_i^2 + \sum_{i=1}^{s} Y_i^2},$$

where S = total number of items, X_i = proportion of item i in the diet of species ×, and Y_i = the same for species Y. Values equal or greater than 0.60 are assumed to represent high dietary overlap.

To compare the proportions of items consumed by a single species according to the season (Dry season – April–September and Rainy season – October–March), points results for diet composition were analysed through a two way ANOVA. Species with low numbers such as *Hollandichthys multifasciatus, Rhamdia quelen, Synbranchus marmoratus*, *Rineloricaria* sp. and *Hoplias malabaricus* were not included in this analysis.

Results

Fish samples collected included 17 species in 9 families, with most numerous species in families Characidae, followed by Pimelodidae and Loricariidae (Table 1). The number of fish species between sites was relatively uniform, while fish density was slightly higher in Site 1, both in the rainy and dry seasons (Table 2). Environmental variables such as water velocity, volume and substrate also distinguished Site 1 and varied according to the season. *Mimagoniates microlepis* was the most abundant species in all sites sampled, representing 48.9% of the total specimens, followed by *Schizolecis guentheri* (20.2%) and *Phalloceros caudimaculatus* (10.0%) (Table 3).

General diet composition analysis of 940 specimens indicated that *M. microlepis, Characidium* sp., *A. leptos, Trichomycterus* sp. and *H. multifasciatus* relied basically on insects, while *K. heylandi*, *S. guentheri* and *P. caudimaculatus* were basically detritivorous, consuming organic matter and sediment (Table 4). Organic matter dominated in *G. pantherinus* and *C. barbatus*, occurring together with insect parts and insect larvae, indicating omnivorous habits for

Table 1. Names, taxonomic position and size range of fishes collected at pedra Branca River.

Family	Scientific name	Main habitat	Size range (mm)
Characidae	*Deuterodon iguape* Eigenmann, 1907	deep pools/ fast water flow	3.1–10.4
	Hollandichthys multifasciatus (Eigenmann & Norris, 1900)	crevices on stream bank	5.7–9.2
	Mimagoniates microlepis (Steindachner, 1876)	deep pools/ low water flow/ under goverhanging trees	1.6–6.5
	Characidium spp.	shallows/ sandy bottom	2.2–5.6
	Astyanax sp.	unknown	2.5
Erythrinidae	*Hoplias malabaricus* (Bloch, 1794)	close to small stream	20.5
Trichomycteridae	*Trichomycterus* spp.	shallows/sandy bottom	2.3–7.3
Pimelodidae	*Rhamdia quelen* (Quoy & Gaimard, 1824)	close to small stream	13.6–29.0
	Imparfinis piperatus Eigenmann & Norris, 1900	under submerged branches	5.5–19.5
	Acentronichthys leptos Eigenmann & Eigenmann, 1890	under submerged branches	3.6–14.4
Callichthyidae	*Corydoras barbatus* (Quoy & Gaimard, 1824)	sandy bottom	3.5–7.1
Loricariidae	*Rineloricaria* sp.	stony bottom	5.5–13.9
	Schizolecis guentheri (A. Miranda Ribeiro, 1908)	sandy bottom/on submerged branches	2.1–4.8
	Kronichthys heylandi (Boulenger, 1900)	on submerged branches	1.3–8.9
Gymnotidae	*Gymnotus pantherinus* (Steindachner, 1908)	marginal vegetation	5.4–27.0
Synbranchidae	*Synbranchus marmoratus* Bloch, 1795	marginal vegetation	30.1–34.0
Poeciliidae	*Phalloceros caudimaculatus* (Hensel, 1868)	marginal shallows	1.1–4.1

Table 2. Physical, chemical and fish population characteristics of the three sites studied in Pedra Branca River.

Site	Dry season			Rainy season		
	1	2	3	1	2	3
Mean area (m^2)	368.3	346.2	371.3	379.0	361.3	389.7
Mean volume (m^3)	78.1	135.8	131.5	81.9	117.4	105.4
Water velocity (cm s^{-1})	45.3	35.8	23.7	51.8	35.5	28.4
Mean width (m)	8.3	7.5	10.7	8.2	8.2	9.2
Tree shading (%)	56.7	75.5	70.6	45.0	79.6	75.2
Stones (%)	15.1	6.5	51.0	0.01	3.4	12.0
Gravel (%)	15.1	15.0	41.3	28.4	28.0	30.0
Sand (%)	33.0	78.5	53.9	29.5	67.6	80.0
Tree trunks (%)	17.3	—	—	6.0	1.0	—
Conductivity (μS cm^{-1})	21.5	23.0	19.6	22.2	23.7	24.2
pH	6.3	6.1	6.3	6.3	6.2	6.3
Number of fish species	14	8	14	15	14	12
Fish density (m^2)	0.34	0.12	0.19	0.26	0.18	0.19

these species. *Rineloricaria* sp. consumed algae associated with organic matter and insects, being also considered omnivorous. *D. iguape* was the only herbivorous species, as pieces of leaves and macrophytes were abundant. Thus among trophic guilds, insectivores were the most abundant group, representing 35.7% of the total species, followed by detritivores (21.4%), benthivores (14.2%), omnivores (14.2%), herbivores (7.1%), and piscivores (7.1%) (Tables 3,4).

Detailed analysis of the diet according to the frequency of occurrence method indicated that a great diversity of insect larvae of different orders occurred, the most common being Diptera, Lepidoptera, Trichoptera, Coleoptera and Ephemeroptera. Items of terrestrial origin occurred almost exclusively in *M. microlepis* and *D. iguape*, comprising Hymenoptera, Hemiptera, Diptera, Thysanoptera and Collembola, among others. Autochthonous insects were common

Table 3. Number of individuals of each species collected at three different sampling sites.

	E1		E2		E3		Total	
	N	%	N	%	N	%	N	%
M. microlepis	334	46.7	258	56.8	236	45.0	828	48.9
S. guentheri	130	18.2	111	24.4	101	19.3	342	20.2
P. caudimaculatus	79	11.0	20	4.4	71	13.5	170	10.0
Characidium sp.	42	5.9	21	4.6	34	6.5	97	5.7
K. heylandi	35	4.9	17	3.7	17	3.2	69	4.1
D. iguape	24	3.4	9	2.0	34	6.5	67	4.0
A. leptos	13	1.8	14	3.1	2	0.4	29	1.7
C. barbatus	4	0.6	0	0.0	1	0.2	5	0.3
G. pantherinus	6	0.8	1	0.2	7	1.3	14	0.8
S. marmoratus	2	0.3	0	0.0	2	0.4	4	0.2
Trichomycterus sp.	15	2.1	0	0.0	6	1.1	21	1.2
R. quelen	4	0.6	0	0.0	3	0.6	7	0.4
I. piperatus	9	1.3	2	0.4	4	0.8	15	0.9
Rineloricaria sp.	8	1.1	0	0.0	0	0.0	8	0.5
H. multifasciatus	9	1.3	1	0.2	5	1.0	15	0.9
H. malabaricus	1	0.1		0.0		0.0	1	0.1
Astyanax sp.					1	0.2	1	0.1

among *Trichomycterus* sp., *Characidium* sp., *G. pantherinus* and *A. leptos* (Table 5).

ANOVA applied to the points method data showed that *I. piperatus* was the only species where significant differences in diet occurred among seasons ($p < 0.05$). Food overlap of Morisita (modified by Horn) calculated from the data obtained for the points method indicated 16 combinations of high overlap (>0.60) (Table 6). Highest overlap values were observed among the detritivorous species (*Phalloceros, Kronichthys* and *Schizolecis*) and the insectivores (*Mimagoniates, Acentronichthys, Characidium* and *Trichomycterus*).

Discussion

Fish composition

The study of the South American streams has dealt mainly with the Amazonian and Paraná catchments. The study of short mountain streams of the Atlantic Cordilheira, the Serra do Mar of Brazil, is only in its beginnings (Por & Lopes 1994). In relation to the fish fauna, Böhlke et al. (1978) and Menezes et al.[3] recommend as the most important and urgent measure the study of these coastal rivers, considering the high level of endemism and the fact that these areas are under great threat from human activities.

Pedra Branca River gives us a good picture of a shaded clear water stream, free of any human impact. In terms of fish community composition, three similar clear water rivers have been studied in the Atlantic rainforest (Sabino & Castro 1990, Uieda 1995, Buck 2000). Comparing the number of species found in the present study (17) with others that found 8 (Sabino & Castro 1990) and 10 species (Uieda 1995) (using gill nets, trap nets, dip nets and underwater observations in the middle course of the river), difference might be attributed mainly to the method of capture. Despite the low conductivity (19.0–24.0 $\mu S\,cm^{-1}$) of the stream, electric fishing was effective in sampling fishes of different size ranges that inhabited different habitats such as crevices, pools, sandy and stony bottom and submerged tree trunks. This resulted in higher number of species than collected via the earlier methods.

Some species, i.e., *Deuterodon iguape, Imparfinis piperatus, Hollandichthys multifasciatus*, *Mimagoniates microlepis, Acentronichthys leptos, Corydoras barbatus* and *Kronichthys heylandi*, are typical endemic species of small and middle sized rivers within the Atlantic rainforest (Britski 1972), whereas *Hoplias, Gymnotus, Trichomycterus* and *Synbranchus* have a wider distribution.

[3] Menezes, N.A., R.M.C. Castro, S.H. Weitzman & M.J. Weitzman. 1990. Peixes de riacho da floresta costeira Atlântica Brasileira: um conjunto pouco conhecido e ameaçado de vertebrados. pp. 290-295. *In:* II Simpósio de Ecossistemas da Costa Sul e Sudeste Brasileira: Estrutura, Função e Manejo, Academia Brasileira de Ciencias do Estado de São Paulo.

Table 4. Diet composition of the different fish species, based on the whole collection period. I = Food Index of Kawakami & Vazzoler (1980); P = Points Method O = Frequency of Occurrence. Predominant food items are underlined.

Food items	*M. microlepis*			*D. iguape*			*K. heylandi*			*Characidium* sp.			*P. caudimaculatus*			*S. guentheri*			*R. quelen*		
	I (%)	P (%)	O (%)	I (%)	P (%)	O (%)	I (%)	P (%)	O (%)	I (%)	P (%)	O (%)	I (%)	P (%)	O (%)	I (%)	P (%)	O (%)	I (%)	P (%)	O (%)
Unicellular algae	0.04	0.36	3.29	1.02	1.99	9.45	5.94	7.10	19.66	0.01	0.01	0.96	3.71	7.45	17.50	5.16	5.89	23.08			
Filamentous algae	0.01	0.10	2.00	3.60	5.59	11.81	3.62	7.02	12.14				0.91	5.12	6.25	1.70	3.72	12.06			
Adult insects	0.50	2.97	5.29	1.88	6.26	5.51	0.00	0.00	0.24	0.22	2.03	2.88									
Insect larvae	1.29	4.24	9.64	0.28	1.62	3.15	0.01	0.15	0.97	24.26	25.43	25.00									
Insect parts	79.23	65.25	38.54	29.62	27.57	19.69	0.00	0.07	0.97	69.81	55.95	32.69	1.10	10.33	3.75	0.01	0.26	1.46			
Vegetal matter	0.05	0.60	2.59	49.50	39.72	22.83	0.63	2.88	5.10	0.96	5.21	4.81	0.12	1.75	2.50	0.49	2.83	4.57			
Organic matter	18.45	23.51	24.91	13.04	12.64	18.90	71.88	55.67	30.34	3.49	6.79	13.46	90.03	60.24	52.50	82.31	67.31	32.22	10.00	10	33.3
Sediment	0.02	0.17	2.94	0.03	0.03	1.57	2.56	7.08	8.50	0.07	0.61	2.88	0.57	2.68	7.50	2.80	8.45	8.73			
Sand	0.03	0.60	1.76	0.03	0.31	1.57	15.8	19.22	18.69	0.40	1.80	5.77	3.54	12.44	10.00	7.52	11.49	17.26			
Crustacea	0.02	0.20	3.06	0.00	0.02	0.79	0.00	0.04	0.73	0.00	0.02	0.96				0.00	0.02	0.21	10.00	10	33.3
Other	0.38	1.99	5.99	1.03	3.98	4.72	0.09	0.77	2.67	0.79	1.97	10.58				0.00	0.03	0.42			
Fishes																			80.00	80	33.3
Number of stomachs	374			37			146			55			29			213			1		
	A. leptos			*Trichomyceterus* sp.			*H. multifasciatus*			*G. pantherinus*			*C. barbatus*			*Rineloricaria* sp.			*I. piperatus*		
Unicellular algae													0.23	0.78	5.88	2.89	4.24	18.18			
Filamentous algae				0.00	0.04	2.38										31.61	30.91	27.27			
Adult insects				0.55	3.58	4.76	52.08	41.48	22.22	0.25	2.30	2.70	6.07	20.19	5.88	7.23	21.21	9.09	18.99	28.13	14.29
Insect larvae	43.06	33.17	30.77	7.20	15.60	14.29	23.25	37.04	11.11	25.64	23.22	27.03				0.41	1.21	9.09	12.45	18.44	14.29
Insect parts	48.20	37.13	30.77	74.53	53.86	42.86				19.58	25.33	18.92	12.14	13.46	17.65				4.22	3.13	28.57
Vegetal matter	4.43	9.11	11.54	0.04	0.49	2.38															
Organic matter	1.48	2.28	15.38	17.21	20.35	26.19	22.78	18.15	22.22	51.53	42.41	29.73	56.33	37.48	29.41	57.84	42.42	36.36	3.59	5.31	14.29
Sediment				0.31	3.98	2.38															
Sand	0.92	5.64	3.85	0.15	1.97	2.38	2.09	3.33	11.11	1.71	3.87	10.81	18.98	21.05	17.65						
Crustacea	1.29	7.92	3.85										0.04	0.14	5.88				60.76	45.00	28.57
Other	0.77	4.75	3.85	0.01	0.13	2.38				1.27	2.87	10.81	6.22	6.90	17.65						
Fishes																					
Number of stomachs	21			23			4			16			5			6			10		

Table 5. Frequency of occurrence (%) of food items of the most frequent fish species of Pedra Branca River in the rainy (R) and dry (D) season. (l = larvae; ad. = adult; n = nymph; p = pupae).

	K. heylandi		*S. guentheri*		*P. caudimaculatus*		*D. iguape*		*I. piperatus*		*H. multifasciatus*		*A. leptos*	
	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)
Aquatic origin														
Unicellular algae	65.8	31.5	51.9	46.8	60.0	35.7	38.1	25.0						
Crysophyta	4.1	2.7	9.6	12.8										
Filamentous algae	20.6	28.8	20.2	33.9	20.0	14.3	42.9	37.5						
Clorophyta			3.9	0.9										
Cyanophyta			1.0	0.9										
Vegetal matter	9.6	16.4	10.6	8.3	6.7	3.3	85.7	68.8					6.3	40.0
macrophyte							42.9	12.5						
Sediment	21.9	15.1	11.5	27.5	13.3	28.6	4.8	6.3						
Sand	56.2	46.6	47.1	29.4	40.0	14.3	4.8	6.3			33.3			20.0
Crustacea	4.1		1.0					6.3	33.3				6.3	
Insect larvae	4.1							25.0	33.3		33.3		37.5	40.0
Diptera	1.4												6.3	
Chironomidae	1.4												25.0	40.0
Culicidae														
Simulidae														20.0
Lepidoptera (l)											33.3			
unidentified larvae			1.0											20.0
Rotifera	1.4													
Colurella sp.			1.0											
Copepoda/ Harpacticoida	2.7							4.8	6.3					
Chydoridae/ *Alona* sp.	1.4													
Fish eggs								6.3						
Fish scales		1.4						6.3					6.3	
Nematoda	6.9	1.4	1.0	0.9				6.3						
Rhizopoda	1.4													
Acarina	4.1													
Terrestrial origin														
Hymenoptera							14.3	6.3			33.3			
seeds							9.5	6.3						
Adult insects	1.4						28.6	6.3	16.7		66.6			
Oligochaeta						9.5								
Leaves (parts)						9.5	18.8							
Arachnidae							6.3							
Unknown origin														
Coleoptera (ad.)						9.5		16.7						
Coleoptera (pupae)														
Diptera (pupae)													6.3	
Insect parts	4.1	1.4	2.9	3.7	13.3	7.1	57.1	81.3	33.3				25.0	60.0
Organic matter	87.7	65.8	78.9	58.7	60.0	78.6	61.9	68.8	16.7		33.3	100.0	18.8	20.0
Other	13.7	2.7	1.0	0.9			4.8	31.3				6.3		
Unidentified ad. insect							14.3	12.5						
No of specimens with food contents	73	73	104	109	15	14	21	16	6	4	3	1	16	5

Table 5. (*Continued*)

	Trichomycterus sp.		*Characidium* sp.		*M. microlepis*		*G. pantherinus*		*C. barbatus*		*Rineloricaria* sp.		*R. quelen*	
	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)
Aquatic origin														
Unicellular algae			3.8		10.8	3.5				50.0		75.0		
Crysophyta										50.0				
Filamentous algae	33.3				3.9	5.3					50.0	75.0		
Clorophyta														
Cyanophyta														
Vegetal matter macrophyte		5.0	3.8	10.3	4.9	7.1								
Sediment		5.0	3.8		1.5	12.9								
Sand		5.0	11.5	10.3	4.4	3.5	20.0	33.3	33.3	100.0				
Crustacea			3.8		4.4	10.0				100.0			100.0	
Insect larvae		30.0	57.7	37.9	21.1	22.9	70.0	50				25.0		
Diptera					0.5	0.6								
Chironomidae		15.0	23.1	24.1	4.9	2.4	30.0	16.7						
Culicidae					2.0	2.4								
Ceratopogonidae		10.0	3.8	3.44	2.0	0.6	40.0	16.7	33.3					
Simulidae						1.8								
Chaoboridae			3.8		0.5									
Lepidoptera (l)					5.9	2.4								
Trichoptera (l)		10.0	7.7											
Coleoptera (l)			3.8		1.5	0.6								
Psephenidae			3.8											
Ephemeroptera (n)		10.0	23.1	10.3			10.0							
Hemiptera (n)					1.5	5.3								
Trichoptera (p) unidentified larvae							10.0					25.0		
Rotifera									33.3					
Colurella sp.														
Copepoda/ Harpacticoida			3.8		2.5	1.8								
Cladocera					0.5				33.3					
Chydoridae/*Alona* sp.														
Fish eggs					2.0	1.2								
Fish scales			3.8			1.2								
Fish													100.0	
Nematoda			3.8		1.0	3.5	10.0	16.7		100.0				
Rhizopoda														
Acarina		5.0	7.69	13.8	4.9	2.4	10.0		33.3					
Terrestrial origin														
Hymenoptera					6.9	4.1								
Seeds						0.6								
Adult insects		10.0	11.5	3.4	15.7	8.8	10.0		33.3			50.0		
Oligochaeta														
Leaves (parts)														
Hemiptera (ad.)						0.6								
Arachnidae					1.0	2.4								
Diptera (ad.)		5.0			1.5	0.6								
Thysanoptera (ad.)					0.5									

Table 5. (*Continued*)

	Trichomycterus sp.		*Characidium* sp.		*M. microlepis*		*G. pantherinus*		*C. barbatus*		*Rineloricaria* sp.		*R. quelen*	
	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)	R (%)	D (%)
Collembola					2.0	0.6								
Unknown origin														
Coleoptera (ad.)		5.0			3.4	2.4								
Coleoptera (pupae)					0.5	0.6								
Diptera (pupae)			7.7		5.4	4.1								
Insect parts	100.0	80.0	57.7	44.8	90.2	84.7	40.0	50.0	66.6	50.0				
Organic matter	100.0	50.0	30.8	3.4	47.6	67.7	70.0	66.7	66.6	100.0	50.0	75.0		
Other			19.2	10.3	12.8	14.7	30.0	16.7	33.3	100.0				
Unidentified ad. insect														
No of specimens with food contents	3	20	26	29	204	170	10	6	3	2	2	4	1	

Table 6. Matrix of dietary overlap between species calculated after Morisita Index (modified by Horn). Species names & have been abbreviated. Values >0.60 considered high.

Species	Ip	Gp	Cb	Rsp	Hm	Rq	Csp	Al	Di	Kh	Mm	Pc	Tsp
Gp	0.093												
Cb	0.287	0.114											
Rsp	0.263	0.001	**0.708**										
Hm	0.587	0.026	0.537	0.509									
Rq	0.103	0.056	0.083	0.086	0.036								
Csp	0.209	0.441	0.347	0.102	0.317	0.013							
Al	0.373	0.422	0.286	0.046	0.421	0.022	**0.918**						
Di	0.125	0.594	0.397	0.293	0.183	0.028	0.588	0.565					
Kh	0.088	0.113	**0.819**	**0.762**	0.306	0.109	0.118	0.087	0.285				
Mm	0.124	0.394	0.504	0.265	0.171	0.041	**0.904**	**0.701**	0.580	0.315			
Pc	0.098	0.114	**0.824**	**0.762**	0.306	0.114	0.260	0.182	0.354	**0.974**	0.477		
Tsp	0.196	0.445	0.527	0.282	0.314	0.040	**0.957**	**0.822**	0.586	0.334	**0.966**	0.480	
Sg	0.090	0.112	**0.762**	**0.748**	0.306	0.118	0.119	0.068	0.274	**0.975**	0.335	**0.978**	0.344

When compared to streams of the Paraná River Basin, the fauna of Pedra Branca River can be considered poor. Garutti (1983) studying a Paraná Basin stream found 30 species, while Pavanelli & Caramaschi (1997) found 54 and 64 species, respectively, in two streams of the same basin. Despite the absence of fish density data for similar rivers, our results indicate that density can be considered low ($<0.5\ m^{-2}$), when compared to the findings of Henderson & Walker (1990), which registered average densities of about 100 fish per square meter within leaf litter banks of Amazonian blackwaters. In this respect, Atlantic rainforest streams seem to differ from Amazonian streams, despite other similarities, noted by Sabino (1999), which indicate structural and functional similarities between fish communities of the two forests, e.g., spatial distribution, diet and feeding behavior.

According to Lowe McConnell (1975) fishes of tropical streams are affected by seasonal changes due to the expansion and retraction of their habitat. Despite the occurrence of a rainy period (November–April), short periods of heavy rains occur throughout the year. Strong spates are characteristic for these coastal rivers, and may according to Grossman et al. (1990) influence fish population size, habitat and food availability.

The results concerning fish richness, density and habitat showed little influence of these events. Considering, however, the results obtained for each species behaviour separately, greater abundances of *Mimagoniates, Schizolecis* and *Deuterodon* were associated with the rainy season, which may have possibly been caused by the recruitment of young individuals (Esteves et al. unpublished).

Resource utilization

Analysis of the food composition in conjunction with the main habitat occupation and activity patterns of some species, suggested ecological segregation existed among species. *M. microlepis*, the dominant species, was very effective in exploiting the surface of deep pools under underhanging trees, capturing terrestrial insects with rapid movements. Nocturnal observations showed that when spates occurred, the amount of drift increased considerably, stimulating a rapid movement of *M. microlepis* towards the surface. These observations and the presence of full stomachs during different times of the day, seem to indicate that *M. microlepis* will feed opportunistically at different periods of the day, capturing food whenever it is available. Observations concerning *M. microlepis* were made by Sabino & Castro (1990) who verified that this species feeds more frequently on the surface than on mid-water.

Although *H. multifasciatus* also consumed terrestrial insects, its low numbers and the grouping of adult insects in a different category than insect parts, probably resulted in a low overlap between this species and *M. microlepis*. Field observations indicated that this species occupied areas close to the river bank.

Among detritivores, although food overlap was high among species, *P. caudimaculatus* occupied shallow regions of the river indicating spatial segregation. *S. guentheri* and *K. heylandi* were usually found nearby, over fallen branches or on the sandy bottom. The high availability of detritus, and associated items such as algae, however, suggests that no intense competitive interactions necessarily occur between these two species. Observations of Buck & Sazima (1995) showed that large individuals of *K. heylandi* in a Brazilian forest stream foraged both day and night, with individuals larger than 80 mm foraging at night, while *S. guentheri* seems to be clearly diurnal.

Within the group feeding on aquatic insects, although high overlap was observed between species, spatial segregation was also observed. *A. leptos* was characteristically found under submerged branches, *Trichomycterus* sp. and *C. barbatus* on sandy bottoms in deeper areas and *Characidium* sp. in shallow areas with sandy bottoms. The sit-and wait behaviour employed by this species, catching single prey items at a time after visual detection (Sabino & Zuanon 1998) may be another mechanism which helps to avoid competition.

Most of the studies of feeding habits of fishes in tropical streams have found a large amount of dietary overlap and a heavy reliance on allochthonous food, mainly terrestrial arthropods and detritus of terrestrial origin (Knöppel 1970, Saul 1975, Lowe McConnell 1975). In contrast to these studies, despite the use of broad food categories, only 15.3% of the species pairs of Pedra Branca River overlapped. This low overlap verified within the community and the field observations that indicated habitat segregations among overlaping species, suggest that food partitioning mechanisms may occur at different levels.

When the number of fish species whose diet has been studied is considered (14), autochthonous food seems to be more important, since only about five species consumed items of allochthonous origin. Considering however that allochthonous feeding species (including here the detritivores) make up 87.2% of the total abundance, the importance of allochthonous food increases, since most of the fish biomass derives from this source.

Differences among results obtained by several authors with respect to the degree of overlap and the main food sources in tropical stream fishes derives from the method employed, the hydrological regime of the stream and the period of sampling, as stated by Moyle & Senanayake (1984). The low overlap and the predominance of autochthonous food found by these authors in rainforest streams of Sri Lanka was partly attributed to a relative constancy of the environment as compared to the studies of Knöppel (1970), Zaret & Rand (1971) and Saul (1975).

This study found a constancy in the consumption of different food items by the fish species, indicating no differences between seasons. These results show that despite hydrological variation produced year round in the form of spates, habitat modifications do not seem to be sufficient to produce drastic changes in food niches as those observed in a Panamanian stream by Zaret & Rand (1971). Thus, although modifications in food abundance may occur during the year, all items are in constant supply. However the food available may be lower than in the studies of Knöppel (1970) in Amazonian rainforest streams, as observed by the low number of individuals found in the drift and benthos (Esteves et al. unpublished), a situation which may explain higher food segregation among species.

The fish fauna of Pedra Branca River is thus mantained by a few resources, of which those of allochthonous origin are fundamental for the mantainance of the greatest part of fish biomass. The small size of most of the species populations, the high number of endemic species and the direct and indirect dependence of food sources that derive from the forest, suggest that the fish populations of these clear water rivers of the Atlantic rainforest are very sensitive to anthropogenic impacts. As deforestation may cause lack of specific animal or vegetal food and increase turbidity and sun light, leading to small-scale but catastrophic extinctions in Atlantic rainforest streams (Menezes et al.[3]), future studies which rely on structural and functional aspects of the biota to assess anthropogenic impacts and priorize conservation efforts are strongly recommended.

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